Expert Systems: A Possible Link from Field Work to Policy in Farming Systems[1]

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Farming systems research (FSR) has taken many forms over the past few years and engendered many disputes. However, its utility in agricultural development is established among a large number of practitioners. Many people have spent years working in remote areas on farming systems projects with farmers and scientists in other disciplines.

During three years of intensive field work and numerous studies in rural Sumatra, we collected a huge body of scientific data. Although much of the information was relevant for project decision making and priority setting, it had wider applicability.

We wanted our research results to serve some practical, people-oriented goals—on as wide a scale as possible. Publication of scientific papers in English is an ineffective method of disseminating the findings to Indonesian hosts and collaborators, as well as to the co-team members from different disciplines. Motivated and interested scientists from one discipline have difficulty understanding papers that meet the technical standards of another discipline (even in their native language).

This quandary prompted experimentation with expert systems. The information collected about people is integrated into an expert system that provides recommendations about agricultural research and development in Indonesia based on a holistic, people-oriented perspective. This is an experiment, and the outcome is uncertain.

There were several considerations in the difficult task of developing FARMSYS, the expert system:

1. There is a general perception that access to sociocultural factors is costly and of uncertain value. A good expert system could provide some of this input at a low cost (both in money and time). An expert system should be able to substitute for a consultant, to some degree.

2. Even in projects where information about people is available, it is sometimes ignored. Agricultural practitioners may be unwilling or unable to read pages and pages of another discipline's jargon (or social scientists may be unwilling or unable

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to describe their findings succinctly and clearly). The expert system software:

- encourages the creators of the system to streamline concepts and definitions and identify causal links; and
- processes most jargon internally so users are oblivious to most of it (although they will encounter some).

Users—whether policy makers or other farming-systems team members—can get a simple, clearly defined recommendation in English (or another language) in a short amount of time.

3. There is great diversity among rural areas of different parts of the world. What works in one place or with one group of people does not necessarily work in another situation. The capacity of the expert system to store vast quantities of location-specific information allows us to incorporate diversity more effectively into decision making at various levels—by making location-specific information available.

4. Anthropologists collect vast quantities of information that can be put into the causal statements required by a rule-based expert system. The process of translating ethnographic information into a series of "if x, then y" rules may elucidate some general principles that escape us when we use our usual approach. This process likewise forces us to identify specific factors that lead to practical agricultural recommendations—something most anthropologists resist.

The Expert System: FARMSYS

Expert systems are computer programs designed to use human knowledge to solve concisely defined problems. Knowledge and experience from human "experts" are incorporated in the program using symbolic logic and heuristics—rules of thumb. Thus, in a quick, consistent and inexpensive manner, the knowledge gathered through years of research can be accessed and applied to specific problems. This artificial expertise is easy to transfer and document and can be made readily available to people in related fields—other researchers, policy makers, educators, and the like.

There are several kinds of expert system software (or shells) currently in use, and more are being developed. We have used EXSYS, version v.3.2 (EXSYS, Inc., Albuquerque, New Mexico, USA), for the system discussed in this paper: FARMSYS.

To use the completed FARMSYS knowledge base, a user will need an IBM-compatible microcomputer with at least 256K of memory. To create an expert system using "editxs," a specially developed rule editor, one needs an IBM-compatible microcomputer with at least 640K of memory. Expert systems as discussed in this paper will be based on the EXSYS software.

The purpose of an expert system is to provide a user with access to knowledge that would otherwise be available only from an expert. Ideally, a user could take an EXSYS program diskette and a diskette with an expert system like FARMSYS on it and receive advice (or a recommendation) on a topic included in the expert system, e.g., a medical diagnosis, a liming requirement (ACID4), or the best kind of fish to stock in a fish pond (FISH). FARMSYS provides recommendations related to agricultural research and development.

EXSYS operates by chaining backwards from each "choice" (or recommendation) through a series of rules (which are constructed in an "if-then" format). This process leads users through a series of questions about their specific situations. The answers to these questions determine the appropriate "choices" (or recommendations) and the probabilities.

Using an expert system is simple, although the information needed to answer the questions it poses may not be available. Creating an expert system, as discussed in this paper, is not easy. As will become clear, we are not yet sure whether it is worth the effort.

The major building blocks of an expert system such as FARMSYS are of three types: qualifiers, variables, and choices. Qualifiers are the most commonly used component in FARMSYS. The following two rules are examples of rules composed only of qualifiers:

RULE NUMBER: 7[1]

IF:	(1) Ethnicity is Minangkabau
THEN:	(1) Landowner is normally considered to be a corporate matrilineal clan.
and	(6) Religion is Muslim
and	(9) People value rice and no-till and water buffalo

RULE NUMBER: 9

IF:	(1) Ethnicity is Kenyah Dayak
THEN:	(2) Land is viewed as abundant
and	(9) Most crops planted probably require minimal management
and	(10) Farm includes upland field

It should be clear from these examples that qualifiers can be clear-cut (religion is **Muslim**) or fuzzy (most crops planted probably require **minimal management**). The system

[1] This information is based on 9 months participant observation and other studies by Collier (1986) in Pulai, and three studies in Koto Padang by Martha (1985), Murni (1985) and Agus (1984).

can incorporate quantifiable variables (domestic animals may include **chickens and pigs**) as well as qualitative attributes (ethnicity is symbolized by **female rice cultivation and male expedition making**).

The boldface parts of each sentence indicate the appropriate "value" selected from several as in the following:

RULE NUMBER: 221

Qualifier #76

IF: People's diets are generally
1. protein poor
2. carbohydrate poor
3. vitamin poor
4. adequate

This rule shows how qualifiers appear on the screen when a new rule is being created. One can select from the values available or add a new value if necessary. All the qualifiers can be reviewed, one by one, at any time by scrolling with the arrow keys.

The second important component from which rules are constructed is **variables**. These were created to handle quantitative material but have been improved to include "string variable" (letters). Variables allow for rules requiring formulae.

RULE NUMBER: 220

IF: (1) [PROPBOUGHTFOOD]> [PROPGARDFOOD] + [PROPDRFLDFOOD] + [PROPHOMGARFOOD]
(2) People's diets are generally adequate

THEN: (1) Experimental crops should be those crops now grown for sale by the people—probability = 75/100

Number 1 in the "if" clause should read "if the proportion of bought food is greater than the sum of the proportion of food from orchards, food from dry fields and food from home gardens." The second component of the "if" clause is a qualifier.

The "then" clause introduces the third component: the choice (recommendation). Each choice (and the probability of it being appropriate and accurate) is the end product provided to a user. A "choice" in a medical expert system might be a diagnosis (the probability of a particular disease, given the symptoms provided by the user). A choice in FARMSYS is a development-related recommendation.

The following rule shows how the choices appear on the right of the screen. Like the qualifiers, choices can be scrolled using the arrow keys. The rule also shows how the screen looks when one wants to edit a "then" clause by adding or changing a choice.

1. Experimental sites should include home gardens—probability = 90/100.
8. Experimental sites should include home gardens
10. Experimental crops should be food crops
11. Experimental crops should be tree crops

In summary, the system takes site-specific information, collected in Indonesian villages, and forms it into "if-then" rules—composed of qualifiers, variables and choices—about people and agricultural research and development. These rules are designed to lead to development-oriented recommendations (choices) for scientists and policy makers, which take people's behavior and beliefs into account. The result is rules that relate to nine Indonesian communities, but we hope to abstract some general principles about people and soil management after successfully describing these specific situations.

The Database

FARMSYS builds on ethnographic (and other) information collected on two projects. The information on the Minangkabau and on Javanese and Sundanese transmigrants was collected under the Tropsoils-Indonesia Project between 1983 and 1986. Field research for FARMSYS was conducted in Sitiung, West Sumatra, a large transmigration area. Major studies related to people were conducted in two indigenous Minangkabau communities (Koto Padang and Pulai) and in two transmigrant communities (Aur Jaya and Piruko) with supplementary studies conducted in three more transmigrant communities (Sitiung II Blok D, Sitiung I Bloks B and D).

The information on the Dayaks of East Kalimantan was collected under a Man and Biosphere project entitled "Interactions Between People and Forests in East Kalimantan" in 1979 and 1980. The field research included in FARMSYS was conducted in Long Segar, a resettlement village two days and one night's river-boat ride from the provincial capital (Samarinda), and in Long Ampung, a remote community in the interior of Borneo, then accessible only by foot. Both communities were inhabited by Kenyah Dayaks.

In both projects, the information for the FARMSYS database was collected using two methods. The primary method was participant observation supplemented with focused quantitative studies. These studies were designed in response to our emerging understanding of local systems, both human and agroenvironmental.

Four year-long time-allocation studies were conducted in four com-

munities using Johnson's (1975) method (see also Colfer 1983, Colfer, in press). Galileo studies on values and perceptions (Woelfel and Fink 1981) were conducted in two Dayak communities (Colfer 1982b), three transmigrant communities, and one Minang community (Colfer et al. 1986, 1987b). Studies of women's status and decision making occurred in two Dayak communities, three transmigrant communities and one Minang village (Koto Padang and Pulai), and in two transmigrant communities (Aur Jaya and Piruko), with supplementary studies conducted in three transmigrant communities and one Minang village (Martha 1985, 1986; Elfina 1985; Colfer et al. 1987a). A number of smaller, special-purpose studies were conducted as well (Chapman 1984, Elfina 1985, Evensen et al. 1985, Evensen 1987, Kan 1987, Naim and Herman 1985).

Another component of the work included collaborative research with farming families. For four years we worked with 13 families designing and conducting experiments on upland fields (Colfer et al. 1984a, Wade et al. 1985, Colfer 1987), one year working with families in a small catchment area, comparing soil-conservation techniques, and another year working with 10 farmers on home gardens, experimenting with organic fertilizers and studying cropping patterns and use of produce (Evensen 1987), fish-pond management and forage-related practices (Evensen 1987).

Current State of FARMSYS

In designing this (fledgling) expert system, three important decisions were required early on: 1) for whom is the system being developed, 2) what "choices" should we provide, and 3) given these, how can the ethnographic information be structured so that differences that are most important arise early on in the rules?

This experimental expert system provides recommendations about agricultural research and development in Indonesia, based on a holistic, people-oriented perspective.

The experience in developing FARMSYS has been one of iterative oscillation in these decisions.

Users and Choices

We considered addressing the system to policy makers, to scientists, to farmers, to extension agents and to co-team members. Farmers and extension agents were ruled out because of the shortage of electricity, computer equipment and computer skills in rural Indonesia. Scientists are the primary audience to whom the current system is addressed. Co-team members are seen as a subset of scientists, recognizing the goal of improving interdisciplinary communication. Policy makers are potential secondary users. They are unlikely to know the answers to the questions that FARMSYS asks. Although this is, to some extent, true for scientists as well, they, by definition, have a mandate to find the answers. Further "oscillation" remains a possibility.

The question of what kinds of choices to provide to the user was, strangely, a difficult one as well. A primary strength, as well as a limitation, of anthropological information is its breadth. The holistic approach, a cornerstone of anthropology, means that to some extent one deals with everything. Which information would be most useful for practical, agricultural purposes? Would it be best to organize information so as to provide users with predictions about existing systems? Or would it be better to offer the user a prescription for something new, based on existing systems?

A starting point was prediction of the crops that would be grown on people's fields. This approach was too static and failed to tap some of the most useful information available. Yet trying to prescribe development strategies seemed too overwhelming at the beginning; describing what existed seemed a sufficiently momentous task.

However, as we progressed in the process of translating anthropological information into "if-then" statements, the idea of making these development-related prescriptions seemed increasingly feasible and desirable. From the point of view of agricultural development, the relevance of existing cropping patterns lies in making decisions about what future cropping patterns to study, develop and extend. So, at this stage the choices prescribe particular courses of action for users (the scientists). More will be said on the kinds of choices offered, but to convey partially the iterative nature of the FARMSYS development process, the structure of the "if-then" rules will be covered first.

Structure of the Rules

Two characteristics emerged immediately as critical for differentiating among the farmers being worked with. Ethnicity and location each significantly affected agricultural practices. Therefore, a series of rules

identifying relevant factors about ethnicity and locations of study appears early in FARMSYS.

Since the information is, to some degree, site specific, it was necessary to indicate how such information is relevant (or irrelevant) in other areas. FARMSYS' first rules appear as a series that provides probabilities for a choice: "Results of this system should be applicable." Rule 1, for instance, is

IF: Location is in Bali, Java or arid Outer Islands
THEN: Results of this system should be applicable—probability = 50%

Rule 5 says

IF: Location is in the Sitiung area of West Sumatra
THEN: Results of this system should be applicable—probability = 50%

The importance of ethnic differences also had to come up early in the system. Rule 11 is provided as an example in its current draft form:

IF: Ethnicity is Javanese transmigrant

THEN: Landowner is normally considered to be a male household head
and Land is viewed as very limited
and Rights to land are traditionally certified and private
and Women's agricultural labor is recognized as necessary but not preferred
and Ethnicity is symbolized by farming and small-scale female trade
and World view is hierarchical and authoritarian
and Domestic animals may include < 2 cows and goats and chickens and 2 or more cattle
and Most crops planted probably require intensive management
and People value fertilizer and hoeing and cattle

Rules 7 and 9, above, provide comparable data on two other ethnic groups. In rule 7, for instance, it is uncertain whether the qualifiers "women's agricultural labor is recognized as essential" and "most crops planted probably require minimal management" apply to Minang generally or only to those in the Sitiung area or to Minang in other areas like Sitiung as well.

Questions such as these will be investigated through the literature initially, and perhaps ultimately through a workshop of agricultural anthropologists with relevant research experience. We hope (and anticipate) that, in compiling data on these quite different farming systems, general principles will emerge that relate to soil management and that transcend locality. Each of the remaining general topics must be dealt with to some extent for each ethnic group.

We have not decided whether location or ethnicity should come first, since they seem to be equally important. Since ethnicity has often been ignored in agricultural research, it is currently placed first. However, ethnicity is an unpopular topic, like tribalism, in modern states. So putting it in a place of preeminence could adversely affect the use of the system. Within the rules related to ethnicity, the Outer Island ethnic groups (Minang and Dayaks) have been chosen first to highlight the significant differences of their systems vis-à-vis the better-known Javanese and Sundanese systems.

Given these locational and ethnic differentiations, next comes a series of topics that vary along these dimensions and that relate to agricultural research and development. The topics so far identified as relevant are discussed briefly, roughly in the order they are addressed in FARMSYS, and examples of rules dealing with each of these topics are provided. All rules in this system contain "qualifiers." Rule 101 provides an example of use of a "variable." Rules 1, 5, 138 and 154 include "choices" and probabilities that the choices (recommendations) are appropriate. The interconnections among these factors preclude strict ordering.

Crops grown. Different ethnic groups, even in the same locations, express preference for, have experience with, and continue to grow different crops (cv. Evensen 1987, Colfer et al., in press, Colfer 1983). Their interest in various crops differs based on such factors as risk, labor requirements, prices, knowledge of management and land availability.

Rule 22

IF: Ethnicity is Javanese transmigrant
and Farm includes paddy field
and Crops are vegetables

THEN: Vegetables may include swamp cabbage

Land use. There are differences in land use, depending on whether the farmers are indigenous Outer Islanders who practice extensive land-use methods or transmigrants from the densely populated island of Java. The former select lands from unused forested areas, appropriate to particular crops.

Rule 34

IF: Location is in Long Segar, East Kalimantan
and Farm includes upland field
and Agricultural labor is sufficient or abundant

THEN: Field is > ha - 5 ha
and Field is newly cut from forest > 30 years old and planted

Transmigrants tailor their cropping and management patterns to the

small, permanent plots they have been given by the government (Fulcher 1982). In all ethnic groups, different cropping patterns and management strategies are used, depending on the kind of field in question (paddy field, upland rice field, orchard or home garden; see Colfer et al., in press).

Division of labor. Although both men and women in all four ethnic groups are involved in agriculture, there are significant differences among them. Among the Dayaks, women are seen as the primary cultivators of rice (the most important crop; Colfer 1981c, 1983, 1985). Rubber, an important crop for the Minang in the Sitiung area, is seen as primarily a men's crop for management purposes, but more than half the rubber is owned by women. Home gardens are seen as primarily women's domain by all the ethnic groups studied (Colfer et al. 1986). The Javanese and Sundanese view farming as ideally a man's occupation, though women "help out" to a substantial degree.

Rule 101[4]

IF: Location is in Piruko, West Sumatra

THEN: [FEMAGLAB] is given the value of 9
and [MALAGLAB] is given the value of 16
and [FEMMARKET] is given the value of 1
and [MALMARKET] is given the value of 0
and [FEMHOE] is given the value of 1
and [MALHOE] is given the value of 8
and [FEMWAGLAB] is given the value of 4
and [MALWAGLAB] is given the value of 8
and [HOMGARTIME] is given the value of 5
and [DRYFLDTIME] is given the value of 11
and [SAWAHTIME] is given the value of 8
and [FEMCUTNCARRY] is given the value of 4
and [MALCUTNCARRY] is given the value of 4

Risks. Risk varies by location and crop. Ethnic groups differ in their willingness to take risks. Therefore, different risk-management strategies are used in different locations. Where unpredictable rainfall makes drought and flooding alternate risks in the same area, the Dayaks alternate two fields (one on high ground and one on a riverbank; Colfer 1983). In the Sitiung area, one response to the multiplicity of agricultural risks is to diversify crops (Colfer et al., in press).

Rule 119

IF: Location is in the Sitiung area of West Sumatra
and Field crop is mung beans or corn or chili

THEN: Risks include insufficient fertility of soil and aluminum toxicity

Animals. In each of the four ethnic groups, animal ownership differs. In the villages where we worked, all own chickens, if possible, but only the Minang keep water buffalo, only the Dayaks keep pigs, and only the Javanese keep cattle, in general (see, for example, Colfer et al. 1980). Differing attitudes and behavior toward manure have important agricultural implications where cash is in short supply to purchase fertilizer.

Rule 143

IF: Ethnicity is Javanese transmigrant or Sundanese transmigrant
and Animals may include cattle or goats
and Farm includes home garden

THEN: People use barnyard manure (Agus et al. 1987)

Land preparation. The Javanese and Sundanese, used to extreme land shortage, are ready and willing to hoe and plow and intensively till their lands—to the extent of their physical capabilities. Outer Island farmers find only minimal amounts of hoeing acceptable. They dibble-plant upland rice and rarely plant any of the other field crops that would require hoeing or plowing unless the anticipated profit is great and their financial situation allows risk-taking (see Colfer 1983, Colfer et al. 1984a, Wade et al. 1985).

Rule 138

IF: Location is in Koto Padang, West Sumatra; or Pulai, West Sumatra; or Long Segar, East Kalimantan; or Long Ampung, East Kalimantan
and Land preparation is dibble stick
and People value no-till

THEN: Experiments on intensive tillage methods are appropriate—probability = 5%

Fertilizer/Inputs. Both willingness and capacity to fertilize crops vary. Outer Island farmers show less interest in fertilizers than do farmers from Java (Colfer et al. 1986, 1987b). Even willing farmers have recurrent problems of cash availability for purchased fertilizers. Javanese farmers with cattle make regular use of their manure as a fertilizer (Agus et al. 1987). Minang farmers never use the manure from their water buffalo as a fertilizer; they burn it as mosquito repellent for the beasts.

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[4] See Colfer et al. 1984b, or Colfer 1981a for Dayaks.

Rule 154

IF: Fertilizer is a kind requiring incorporation
and Land preparation is hoeing
and Most crops planted probably require intensive management

THEN: Experiments on intensive tillage methods are appropriate—probability = 80%
and Experiments on levels and kinds of commercial fertilizer are appropriate—probability = 80%

Income. People's incomes influence their willingness and ability to risk cash on agricultural inputs. In places like Long Ampung, where there are not regular sources of income or agricultural inputs, agricultural improvements must capitalize on such strategies as alternate tillage methods or use of indigenous materials for organic matter.

Rule 146

IF: Location is in Long Ampung, East Kalimantan

THEN: Money is rarely used and in short supply
and Selling produce is difficult and disvalued and rare
and Access to location is difficult on foot and expensive by small plane

These remain important in the other areas, simply because of the low levels of income available to most farmers.

Production. Rice-production levels in Kalimantan influence people's interest in clearing forest for new fields (Colfer 1982a). Production levels are a major factor in whether transmigrants are trying other crops. Increasing production is viewed as irrelevant for most crops by farmers in purely subsistence areas such as Long Ampung or for subsistence such as swamp cabbage or cassava leaves in other areas.

IF: Location is in a difficult place to reach
and Money is rarely used
and Selling produce is difficult
and Nutritional status is adequate

THEN: People's agricultural goals are not to maximize production

Such differences must be taken into account in moderating the tendency for some agricultural scientists to focus only on increasing production. Farmers' interest in production is closely tied to marketing potential.

Nutrition. Nutritional status in all the groups with access to markets is marginally adequate. It may actually be adequate in Long Ampung, though the evidence is only observational and short term (Colfer 1981a, 1981b). It almost certainly declined with access to markets in Long Segar, relative to Long Ampung. Differing crop marketing and dietary patterns among the different groups suggest that a variety of strategies for enhancing nutritional status by agricultural means is in order.

Rule 168

IF: Location is in the Sitiung area of West Sumatra
and Ethnicity is Javanese transmigrant
and Field crop is upland rice or cassava or paddy rice

THEN: This food is a staple

Structure of the Choices

Just as the rules are organized into a hierarchical structure to some extent, it makes sense to organize the choices (recommendations) in some way. EXSYS (the program) begins with the first choice and tries, by going through the rules, to provide the user with that recommendation. It then goes on to the next choice and does the same thing.

In this case, the choices are recommendations designed for agricultural scientists and are organized into a logical order according to their decision needs. It is assumed that the scientists may be working with farmers and that they are trying to design their experiments in such a way that their results will have the maximum probability of being usable by farmers. The user is allowed to specify the scientist's or policy maker's goal for the research—whether it includes increased production only, equity only, production and equity, improved nutrition and/or increased financial security for all family members or for only the head of the household.

The first series of choices, or recommendations, relates to which *farmers* the scientist should be working with. These choices specify female farmers, male farmers, both sexes, a fair mix of ethnic groups, and a fair mix of clans resident in the area. This should serve to widen the perspective of users, since there is a tendency to work with male farmers from Indonesia's dominant ethnic group.

The second series of choices helps the scientist choose a *type of field.* The choices at this stage are upland fields, paddy fields and home gardens. Again, this may serve to widen the realm of agricultural endeavor, since very little research is currently done on home gardens. Home gardens already supply large portions of income and food for transmigrants (particularly in the early years of settlement); they represent the "best bet" for improved nutrition in some areas, and they hold much potential for working with female farmers (Colfer et al. 1985).

Our third series of choices recommends *crops* to be used in experiments. Most agricultural experiments in Indonesia are performed on field crops. Yet in the infertile areas of the Outer Island, tree crops appear

much better adapted to local conditions; they can sometimes provide a source of cash and require less labor. Another neglected kind of crop with important nutritional advantages is vegetables. Pasture and fodder crops may save transmigrant cattle owners considerable time (given their cut-and-carry feeding system, as well as supplying a source of organic matter (a valuable soil amendment).

The integral role of rice cultivation in Dayak life would make the adoption of alternate field crops less likely than for the Javanese, who show interest in a variety of crops. Experiments using rubber trees as a crop would make more sense among ethnic groups with experience growing, processing and selling that crop. In the Sitiung area, rubber growing has taken on symbolic value as an ethnic marker, making it less attractive to non-Minang farmers.

The last series in the list of choices relates to specific *kinds of experiments* appropriate under differing conditions. Some examples follow.

Given the lack of interest and experience of the Minang and Dayaks with hoeing upland field crops, experiments that require incorporation of fertilizers or lime prior to planting are unlikely to lead to popular technologies; with the transmigrants, however, such experiments could yield a high adoption payoff (if funds were available for purchase of inputs). Research on minimum tillage would at least initially be of little interest to transmigrants, whereas Outer Island farmers could be expected to take to it immediately.

Experiments and technologies requiring manure use among the Dayaks would probably be of little value, since Dayaks express extreme revulsion at the thought of handling manure. Javanese cattle owners, however, handle manure regularly and would benefit from such experiments.

Experiments on spacing of food crops may best be done with female farmers since they are often in charge of planting. Similarly, studies of herbicides might best be done with women, those who do the work often have the most motivation to reduce labor input. Conversely, experiments on land preparation or techniques for felling large trees (in land clearing) are, in most cases, more appropriate for male collaborators.

All of these choices must, of course, be evaluated by the scientists themselves, taking into account other more agroecological factors as well as their own areas of expertise. The recommendations are designed to mirror what an anthropologist (with some familiarity with things agricultural) would suggest, based on fairly intimate knowledge of these farming systems.

Summary

This endeavor is at a very early stage, and obviously a great deal of work remains to be done. It remains to be determined if the relevant aspects of local farming systems can be effectively depicted within this "if-then" framework. Information on various locations and ethnic groups is being incorporated in the search for principles applicable in other, quite divergent areas.

The most fundamental problems encountered with the approach include the following:

1. EXSYS uses the qualifiers and variables provided in the if-then rules to determine what information it needs from a user. It then asks the user for that information. In FARMSYS, as well as ACID4, the answers to many of the questions are unlikely to be readily available.

In FARMSYS, there is quite a bit of quantitative information on time allocation and on dietary patterns of different ethnic groups. As the system now stands, it asks users questions like "what percentage of total adult time is devoted to agricultural activity in the home garden?" or "what proportion of food items other than rice are green leafy vegetables?" No one has answers to such questions for the vast majority of rural villages.

One possible solution is to delete such specific quantified data and rephrase the information in more qualitative terms (so that a question would be phrased generally: "do people eat a little, an average amount, or a lot of green leafy vegetables?")

2. Specific and extensive information on the Sitiung area of West Sumatra and on two areas in East Kalimantan is available. However, there is currently no way to extrapolate from such specific information to other areas that undoubtedly have a lot in common with these locations.

A possible solution to this problem would be to develop analogies within the system. Rules would have to be developed to guide users to a data set that would be the closest to their case: "If your case is in a very remote area, Then select location is Long Ampung." or "If your case includes people from a densely populated rural area, Then select ethnicity is Javanese transmigrant."

3. The probabilities that are assigned to the choices (recommendations) are currently determined simply by qualitative "feel"—pure judgment, largely on Colfer's part. A more systematic method is important in the long run. Certainly some effort needs to be devoted to developing a consensus among us and, ideally, some other social scientist with experience in Indonesia.

4. The system works best when rules occur in a hierarchical manner, with the most important factors/differentiations occurring early on. The four ethnic groups, for instance, are

on the same level of importance; yet an arbitrary selection must be made simply because the system operates in order. Arbitrary ordering choices have had to be made at every level within the system.

No real solution to this problem seems possible, and the importance of the problem is unclear.

To end on a positive note, the aspects of the system that are appealing include the following:

- It can handle large quantities of complex data (qualitative as well as quantitative) and incorporate them quickly into a chain of links leading to a recommendation.
- It provides a mechanism whereby someone from another discipline can get an "expert opinion"—an answer—without having to learn a whole new set of jargon and methods. The system allows the user to ask how the answer was derived (by displaying the rules used).
- It seems to offer a possible avenue for feeding village-based information to policy and decision-making centers of government.

We continue to think expert systems hold some promise for making "people factors" more accessible and perhaps thereby better integrated into research and development.

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